HNL Prompt Progress: Improving Kinematic Reconstruction

RAL ATLAS Physics Discussion, Zoom Land

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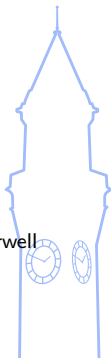
December 1, 2020

Introduction / Refresh

- HNL or type-I seesaw

- Current Run 2 analysis looking for a resonance below the mass of the W via displaced tracks tracks at low mass or high mass LFV (prompt)

- Prompt relies on Same Sign Same Flavour pair

- Possible LNV vs 'LNC + mix' signal extraction under study (spin correlation effects)

- With Giacomo from Pavia I have been studying using MET to improve the reconstruction of the the event

- Work in progress, useful plot ideas appreciated
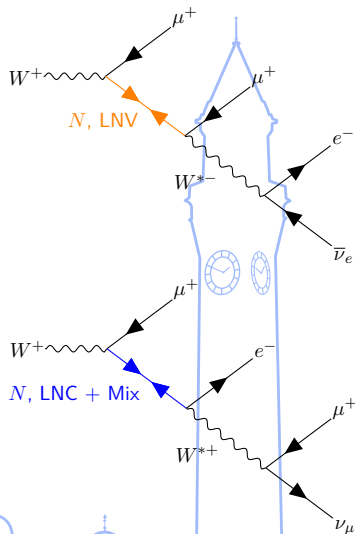
Previous analysis

- Previous analysis used a reasonably simple set of cuts to optimise signal significance with limited combined variables.

- The signal region was binned in mass of the lowest pt leptons to seperate mass hypothesis. Correlated but not particularly sharp.

How to use MET
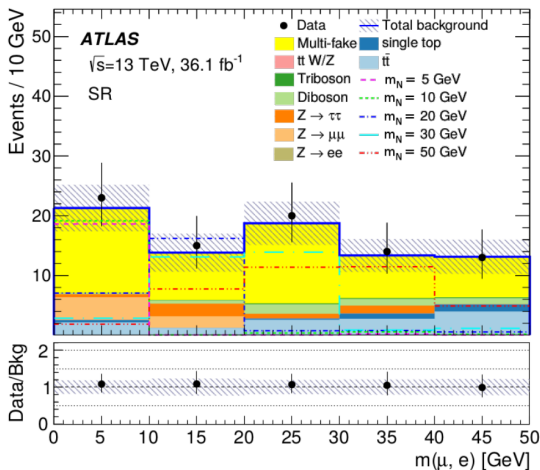
- Not particularly complex: to leading order you only have one missing neutrino and your signal events should come from a W. Solve for $p_{z,W}$

- Once have full kinematics, have to pick an assignment for the HNL decay products

- Quadratic ambiguity $(\cos\theta^*_{\mathsf{HNL}} = \pm a)$/no root has small effect mostly at small m_N

Kinematics for heavy neutrino production

$pp \rightarrow W$, $W \rightarrow HN\ l1$, $HN \rightarrow l2\ l3\ n1$

Final state:
- 3 leptons (3,4,5)
- 1 neutrino (6)
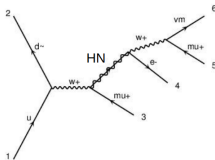
Measured quantities
- 3-momenta for 3 leptons
- p_x^{miss} = neutrino p_x
- p_y^{miss} = neutrino p_y

W is on-shell, → mass constraint:

$(p_{l1}+p_{l2}+p_{l3}+p_{n1})^2 = m_W^2$

Only neutrino p_z unknown, use the W mass constraint to calculate it

Giacomo's Talk

Why use MET

- *At particle/parton level*, get very strong peaks
- I am investigating how well this setup works on real data and how the data is smeared
- It is possible that if you put in all the kinematics into a decent sig vd bkg classifier it would unpack this but useful to understand and feed in sensible values
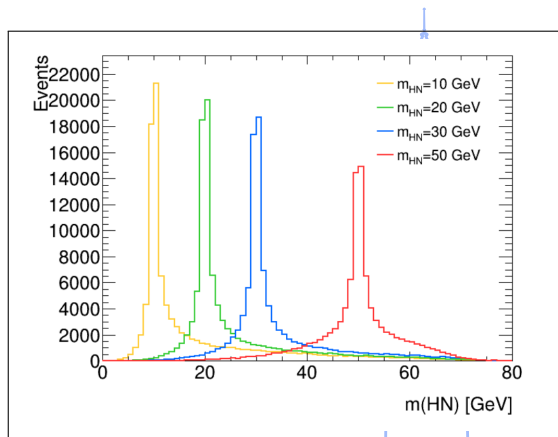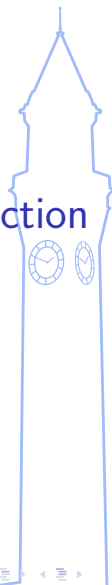

Giacomo's Talk

Part II

# First attempts on ATLAS reconstruction

First Steps

- Some caveats:
  - ▶ The DAODs I use do use a generator without spin correlations which may have a small effect, however this is nearing readiness
  - ▶ No samples greater than 50GeV(yet)
  - ▶ All μ mixing on next plots, but e on later slides with similar picture
- Ran Giacomo's reconstruction on our ATLAS simulation data.
- The major loss of reconstruction power by inspecting the data is truth vs reco MET

50 GeV m_{HN} distribution
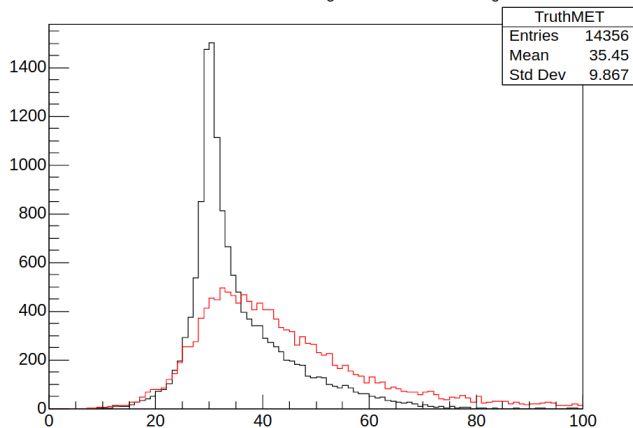

Reconstructed Mass of HNL using Truth vs Reco Event MET

TruthMET	
Entries	18745
Mean	50.30
Std Dev	7.190
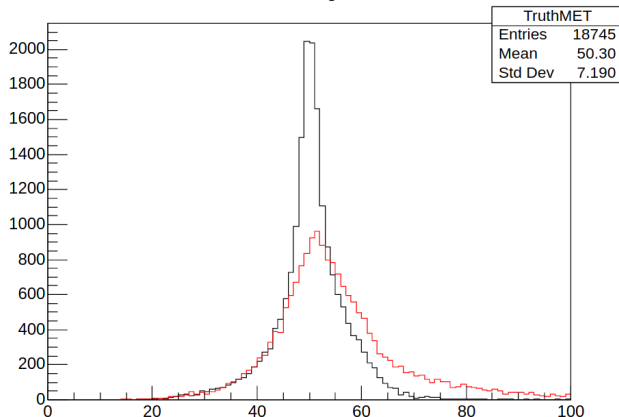
user.safarzad.308982.Pythia8EvtGen__A14NNPDF23LO__WmuHNL50_50G_lt01dd_lep-
filt_ch1.SUSY2.mc16e.p4149.HNL_RD.01Nov20_HFntuple.root

30 GeV m_{HN} distribution

Reconstructed Mass of HNL using Truth vs Event Missing MET

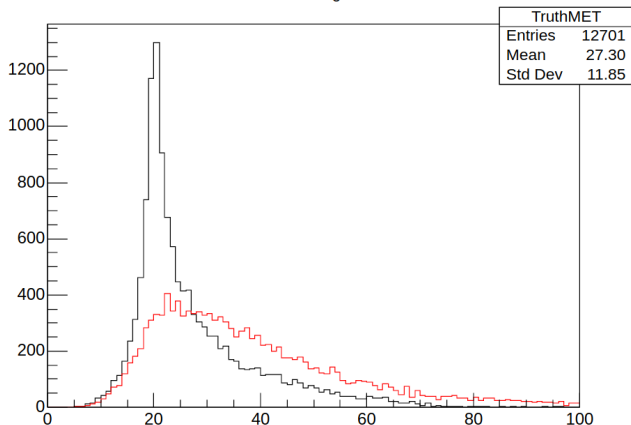| TruthMET	
Entries	14356
Mean	35.45
Std Dev	9.867

user.safarzad.308978.Pythia8EvtGen__A14NNPDF23LO_WmuHNL50_30G__lt01dd_lep-filt__ch1.SUSY2.mc16e.p4149.HNL__RD1.02Nov20__HFntuple.root

20 GeV m_{HN} distribution

Reconstructed Mass of HNL using Truth vs Reco Event MET

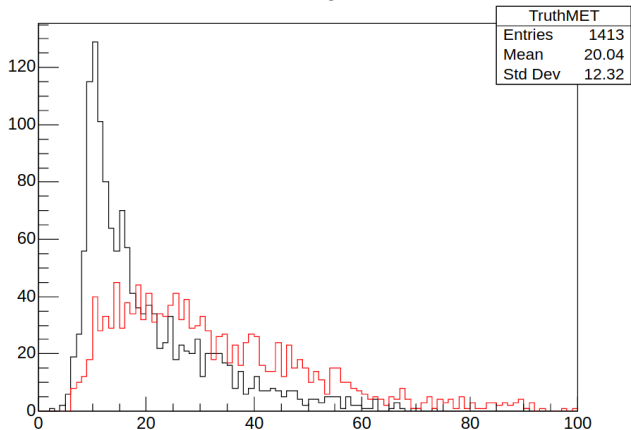| TruthMET	
Entries	12701
Mean	27.30
Std Dev	11.85

user.safarzad.308974.Pythia8EvtGen__A14NNPDF23LO__WmuHNL50__20G__lt01dd__lep-
filt__ch1.SUSY2.mc16e.p4149.HNL__RD.01Nov20__HFntuple.root

10 GeV m_{HN} distribution

Reconstructed Mass of HNL using Truth vs Reco Event MET

TruthMET	
Entries	1413
Mean	20.04
Std Dev	12.32

user.safarzad.308990.Pythia8EvtGen__A14NNPDF23LO__WmuHNL50__10G__lt1dd__lep-filt__ch1.SUSY2.mc16e.p4149.HNL__RD.01Nov20__HFntuple.root

Part III

## A bit more on MET
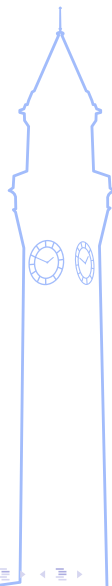
So what does the smearing and shifting?

- Two driving factors:
  1. Low MET resolution is clearly going to cause issue for low mass HNLs
     - ★ I have some plots that show MET resolution error of $\sim 10\,\text{GeV}$ for truth vs reco, ran out of time putting this together.
  2. Higher hadronic activity (H_T)
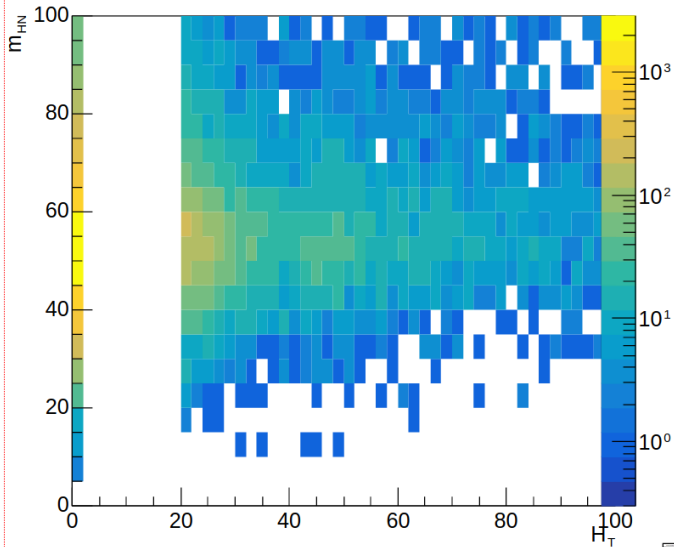   - ★ The following plots show the effect of H_T on the mass
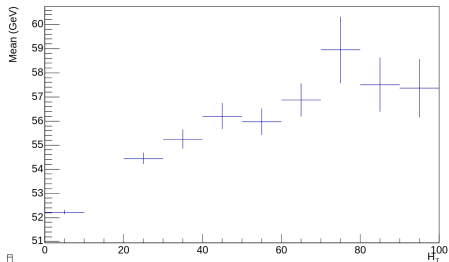
Breaking down this TH2...

Y projection
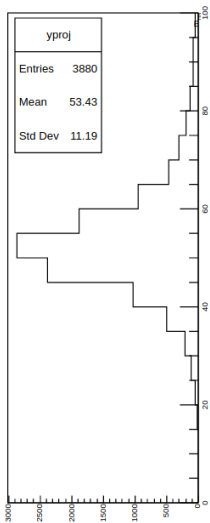
Reconstructed Mass of HNL using reco MET vs H_T
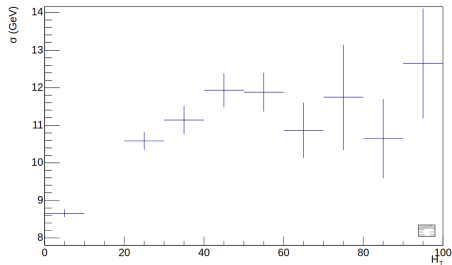
Fitting Slices
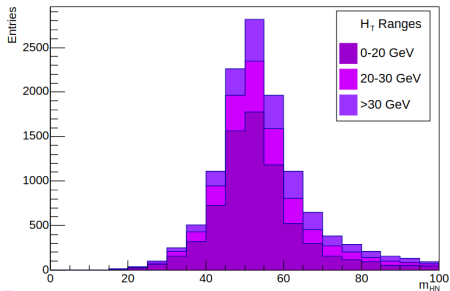

Mean from guassian fit aginst H_T, μ mixing

Standard error from guassian fit against H_T, μ mixing

Expected trend of spread shift
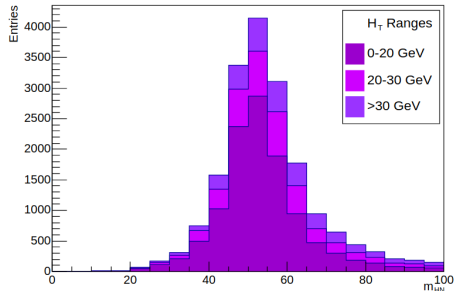
Some more thoughtful slices: 50 GeV
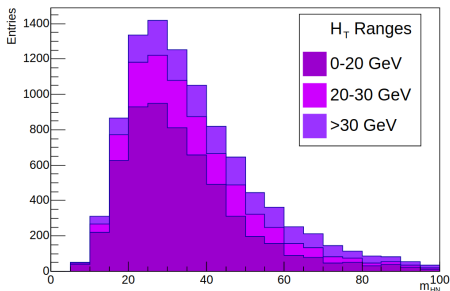

m_{HN} distribution stacked in H_T, m_N = 50GeV e mixing

m_{HN} distribution stacked in H_T, m_N = 50GeV μ mixing
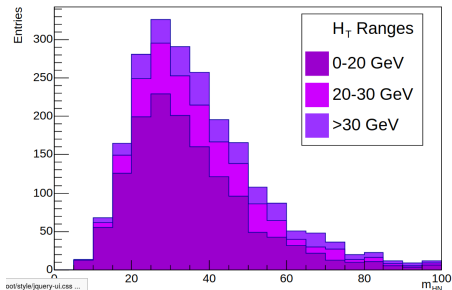
Some more thoughtful slices: 20 GeV

m_HN distribution stacked in H_T, m_N = 20GeV e mixing

m_HN distribution stacked in H_T, m_N = 20GeV μ mixing

Thoughts/Conclusions

- Understand the detector resolution effects of trying to reconstruct the mass of the HNL better
- Can start to think about if/how to use H_T for better sensitivity
- Next steps:
  - Start using background samples to see rejection power
  - Examine the CMS angular distributions to try and obtain further insight

A bit more on bjorken...

- Getting m_{HN} gets you the boost of the W and or a naive guess of x_1, x_2

- This gives you a hint to direction of origin of a quark vs anti quark via PDFs

- This marginally untangles your angular part of the differential cross sections

- Could this be used a way to observe BDT selection or add in as parameter for LNC LNV? Effect likely marginal but want to have a look.
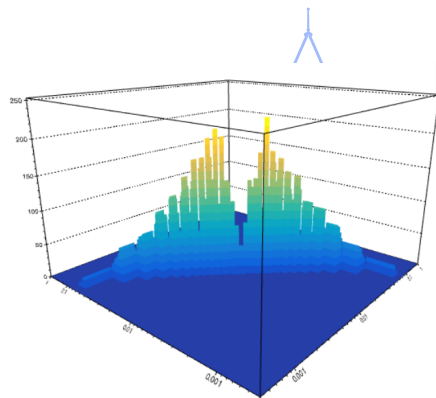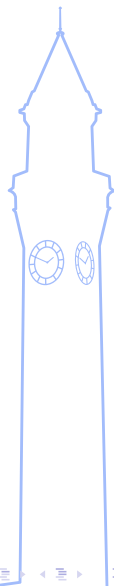

Already computed the distribution

Part IV

Backup

HNLReco

red: without